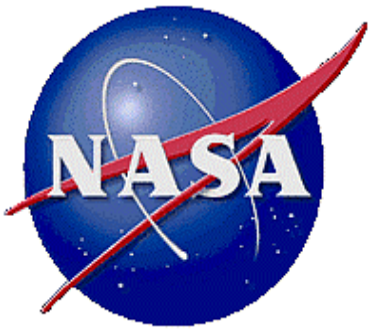

Program Plan
For the
NASA Software Independent Verification and Validation Program

May 2004

Revision 1

Submitted by:

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1 Introduction

As a leader in the space industry, NASA depends on the high quality and reliability of the software developed for its missions. In recognition of the benefits of and need for Independent Verification and Validation (IV&V), NASA established the IV&V Facility in October 1991. This action, initiated by Senator Byrd through the Fiscal Year (FY) 1992 VA-HUD-Independent Agencies Appropriations Act (P.L.102-139), addressed recommendations made by the National Research Council (NRC) and the Report of the Presidential Commission on the Space Shuttle Challenger Accident. The mission of the Facility, located in Fairmont, West Virginia, is "to ensure that our customer's mission critical software and systems are of the highest quality and are reliable and safe by applying software and systems expertise and tools, while researching new approaches, deploying innovative solutions, providing a learning environment, and participating in the vitality of the community" ("Mapping a Successful Future", IV&V Facility Implementation Plan, 2003 – 2008).

The major objectives of the software IV&V process are to determine that the software performs its intended functions correctly, ensure that the software performs no unintended functions, and to provide quality and reliability information. Software IV&V examines the software within the domain of the system being constructed with the objective to determine how well the software meets the technical, safety, security, and reliability requirements of that system. By taking a system level approach to the analysis, software IV&V can also assure that there are no conflicting requirements among system components. Software IV&V strives to analyze, review, demonstrate or test all mission/safety critical software development outputs.

In the years since the inception of the IV&V Facility, the organization has undergone significant changes. Initially, the IV&V organization was part of the Office of Safety and Mission Assurance (OSMA), Code Q, at NASA Headquarters. Subsequently, the organization was transitioned to the leadership of the Ames Research Center (ARC). In 2000, NASA was charged by House Conference Report 106-379 to reexamine the role of IV&V within the Agency. The result of this reexamination was the transitioning of the organization to the leadership of the Goddard Space Flight Center (GSFC). The IV&V organization was embedded in the Office of Systems Safety and Mission Assurance (OSSMA) at GSFC, Code 300. During this time NASA Policy Directive (NPD) 8730.4 was signed, establishing a policy for IV&V across the Agency and a Program Plan was endorsed by all the Enterprises.

In early 2003, the Agency once again reviewed the status and implementation of IV&V. An IV&V Assessment Team was formed consisting of representatives from Headquarters and across the various NASA Centers. The IV&V Assessment Team had seven goals:

1. Status current IV&V procedures, processes and products.
2. Determine the level of Agency penetration of IV&V.
3. Compare the NASA approach to IV&V to the Department of Defense (DoD) approach.
4. Gather IV&V customer feedback.

5. Determine the impact of IV&V on Projects, the Enterprises, and the Agency.

6. Gather Program/Project cost profiles for Software Engineering, Software Assurance and IV&V.

7. Compare the NASA approach to IV&V with the Software Industry's approach.

The IV&V Assessment Team concluded its work with several recommendations for IV&V within the Agency that are listed below:

- Create a single management source for IV&V functional oversight at Headquarters (Code Q).
    - Responsible for IV&V Facility budget and Program Operating Plan (POP) inputs (roll up).
    - Creates and maintains Policy and Guidance for IV&V.
        - Do yearly IV&V process verification to assure compliance, capability and accountability.
        - Assure adequate balance between software assurance and IV&V tasks.
    - Establish Center and Enterprise liaisons to work with Center Projects, Enterprise Programs and the IV&V Facility.
        - To coordinate between Headquarters, Center and IV&V Facility on IV&V related topics.
        - To coordinate with Code Q on yearly assessment of IV&V Project utilization.
        - Provide customer feedback of IV&V performance to IV&V Facility and NASA Headquarters.
- Establish Headquarters IV&V Review Team (Code Q, Code AE, Enterprises and IV&V).
    - Select Projects that require IV&V support.
    - Recommend yearly funding for IV&V.
    - Review yearly IV&V budget actuals and accomplishments.
- Establish Transition Team to implement recommended changes.
    - Revamp Project self assessment criteria, process, and third party review.
    - Revamp Agency requirements for IV&V (e.g. Standard IV&V tasks list).
    - Document IV&V cost model.
    - Create an IV&V Work Breakdown Structure (WBS).

- IV&V Facility to address finding concerning lack of metrics.

The NASA Executive Council supported the recommendations. The following actions were taken in response:

- IV&V was established as an Agency level program under Code Q.
- An IV&V Board of Directors (IBD) was chartered as the IV&V Review Team.
- A Transition Team (led by the IV&V Facility) was formed to address the recommended changes of the IV&V Assessment Team.

In June 2003, the IV&V organization was moved into the IV&V Program Office which was formed under the auspices of the OSMA (Code Q) at NASA Headquarters and overseen by an Agency level IBD chaired by the Associate Administrator (AA) for Code Q. The Program management was delegated to the GSFC and the IV&V Facility Director was designated the IV&V Program Manager. The IV&V Program Office was made part of the Center Director's Office at the GSFC, Code 180, and the Facility management moved from Code 300 to Code 180.

1.1 Scope

The scope of this Program Plan covers those activities established to effect the OSMA IV&V Program. This includes IV&V services, IV&V internal research, educational and community outreach activities along with infrastructure support.

1.2 Purpose

With the revision of the IV&V Program at NASA Headquarters and the changes that have taken place since the 2001 IV&V Program Plan was published, it became necessary to develop an updated version of the IV&V Program Plan. The purpose of this 2004 Program Plan is to:

- Provide an overview of the IV&V Program as it now exists including objectives, goals, requirements, authority and management structure;
- Provide an overview of the processes and controls associated with the evolving IV&V Program including customer advocacy, resource planning and funding, data management, risk management, acquisition and reviews; and,
- Identify the relationships and interfaces between the revised IV&V Program and other Programs and Agreements.

The emphasis of this Plan is to document the objectives and goals of the OSMA software IV&V Program along with the approach used to apply IV&V to NASA Projects. Identification of potential IV&V budgets and staffing profiles will require updates on an as-needed basis. Projects, budgets, and staffing projections will be documented annually in a separate Operating Plan.

2.0 IV&V Program Objectives and Performance Goals

The IV&V Program objectives are focused on supporting the needs of the Agency and the developmental Projects within the Agency. The performance goals and associated metrics are designed to show how well the IV&V Program is meeting its objectives.

2.1 Program Objectives

The objectives of the IV&V Program are threefold: provide high quality software IV&V services to NASA Programs and Projects with mission/safety critical software; perform leading edge IV&V research that will continue to enhance the IV&V services; and engage the public and local community in the experience of exploration and discovery that drives NASA.

The focus of the IV&V services objective is to provide value-added, high quality, technical assurance that the mission/safety critical software being developed for NASA missions is meeting its requirements in terms of the technical, safety, security, and reliability objectives of that mission. In the process, the IV&V Program also seeks to identify, understand and mitigate risks associated with the mission/safety critical software, increase the probability of success of the mission as a whole while reducing software development cost and development time.

The focus of the research objective is to improve IV&V effectiveness and measure our results. Specifically, the IV&V Program is to develop measures of effectiveness; evaluate comparative effectiveness of IV&V approaches, methods, and tools; and develop improved IV&V tools and techniques. The end result is to have an optimized approach to IV&V services in which the Project can see a measurable improvement in mission/safety critical software assurance as well as a reduction in product rework.

The focus of the outreach objective is to support the NASA goals of inspiring and motivating students to pursue careers in science, technology, engineering and mathematics while inspiring the local community to be involved and share in the exploration and discovery experience.

2.2 Performance Goals

The IV&V Program performance goals are linked to the IV&V Program objectives mentioned above, as well as the goals within the NASA 2003 Strategic Plan, GSFC FY2004 Implementation Plan and the IV&V Facility Implementation Plan, "Mapping a Successful Future", 2003 - 2008. These performance goals are identified below:

- Institutionalize IV&V services throughout NASA as a natural 'best practice' and as a wise investment of time and resources.
- Become nationally recognized as a preeminent leader in IV&V expertise, tools, and processes.
- Develop fully a recognized and valued IV&V research presence.

- Establish a desired organizational culture that engages and rewards employees and cultivates their long-term commitment to the NASA IV&V organization's goals.
- Ensure a focus on customers that is second to none.
- Achieve continued quality improvement, compliance, and innovation throughout the NASA IV&V organization that advance effective and efficient operations.
- Capitalize on appropriate direct and collaborative opportunities to ensure maximization of existing resources and advance planned future growth.
- Be an active partner in our communities' future through educational and community outreach activities, and proactive service.
- Ensure a safe, comfortable, and well-equipped workplace that is conducive to high performance and supports individual and team productivity.

3.0 Customer Definition and Advocacy

3.1 Customer Definition

The IV&V Program customer base potentially consists of all NASA Programs and Projects possessing software components. However, the active customer base at any given time consists of those NASA Programs and Projects that have NASA mission/safety critical software components under development. This may include both flight Programs and non-flight Programs that range from the Space Shuttle to the Integrated Financial Management Program (IFMP) which supports the Agency's business needs. The current IV&V customer base is defined by the process described in sections 6.1-6.3.

3.2 Customer Advocacy

Our customer advocacy related processes provide vital data for the IV&V Program in terms of our customer satisfaction levels. Customer advocacy related activities include both formal and informal activities and provide the means/interface for our customer's voice. In addition to monitoring customer satisfaction levels, we also recognize the need to be advocates for our customer. As such, the IV&V Program supports activities such as independent reviews, lifecycle reviews, failure review boards, etc serving as an independent, objective and impartial voice for our customers.

3.2.1 Formal Activities

Formal activities include conducting independent surveys and the collection of performance metrics.

Independent surveys are used to solicit customer feedback. Three survey instruments are used, one after startup, one while the IV&V activities are being performed, and another

subsequent to the IV&V activities being completed. This process is designed to gain direct information on items including quality of work, timeliness, customer interaction, etc. The results of these more formal, structured inquiries are used by Facility Management to initiate corrective/preventative actions and risk management activities, expand on our lessons learned database, and drive our reward and recognition activities.

Internal performance metrics are collected and compiled to identify and trend the IV&V Program's state in terms of quality, deliverable/delivery schedules, and customer feedback. These metrics are reviewed by Facility Management and with our support contractors on at least a quarterly basis, as well as upon indication of any negative concerns or trends.

3.2.2 Informal Activities

Informal activities include holding face-to-face meetings and briefings with our customer base, as well as incorporating our customer into the upfront IV&V planning activities and routine lifecycle related activities. These activities are described further below.

Face-to-face meetings include but are not limited to Director to Director meetings, IV&V Project Manager to Program/Project Manager meetings, etc. Director to Director meetings are conducted on a quarterly basis, whereby the IV&V Director and the organizational leaders of our customer base discuss the status of the IV&V Program's current support to the organization, any overarching concerns/highlights, future work and any other subjects deemed appropriate. IV&V Project Manager to Program/Project Manager meetings and briefings are conducted on a regular basis (monthly, bimonthly, etc) to facilitate an exchange with our customer base to include general status reporting, identification of issues/concerns, etc.

Customer participation is proactively sought in the upfront IV&V planning activities early in the Project planning lifecycle via initial contact/dialog with a Program/Project. During these discussions, our customers are asked to complete an IV&V criteria self assessment for the identified Program/Project. IV&V reviews this self assessment data and holds further discussions with the Program/Project to clarify any self assessment data and discuss the apparent, if any, appropriate levels of IV&V support. Although, IV&V support of a Project may vary based upon funding levels and priorities.

Using the self assessment data, as well as data from any startup assessment activities, a formal agreement is generated by the IV&V Project Manager and the Program/Project to define the agreed upon support by the IV&V Facility, and the interfaces with the Program/Project. Specific items included in the formal agreement routinely include but are not limited to schedule, details of work to be performed, deliverables or products, points-of-contact, etc (this formal agreement is updated as necessary as additional Program/Project data is received).

As mentioned previously, a goal of the IV&V Program is to maintain a focus on customers that is second to none. With this in mind, as the IV&V activities are initiated and services are performed, the IV&V Project Manager is expected to maintain frequent contact with the appropriate Program/Project person(s) on a working weekly or day-to-day basis. As services are performed, results are obtained and initially communicated to the Project by the IV&V Project

Manager to the appropriate Project personnel prior to official release. This dialogue allows us to communicate our concerns to the Project first and provide them the opportunity to resolve them at the working level if possible or at least to avoid/remove any errors or misunderstandings in the results, as well as facilitate a good working relationship with our customer base.

4 Program Authority and Responsibilities

This section of the Program Plan describes the authority, delegation of authority, management structure and responsibilities of IV&V Program participants pertaining to all phases of the IV&V Program, from development of the annual Program budget guidelines through the completion of individual IV&V Projects. Figure 1 describes the management structure and participants associated with the IV&V Program.

4.1 Program Authority

The NASA IV&V Program is governed by NPD 8730.4, which is applicable to NASA Headquarters and NASA Centers, including Component Facilities, and to the Jet Propulsion Laboratory (JPL) to the extent specified in the contract.

Program authority is delegated from the AA for the OSMA, Code Q to the Director of the GSFC via a Program Commitment Agreement (PCA). The Center Director established the position of IV&V Program Manager. Working directly for the Center Director as Code 180, the IV&V Program Manager manages the IV&V Program Office and is the Director of the IV&V Facility. The Project Managers for each IV&V Project are responsible for the overall success of the individual IV&V efforts applied to a developmental Project and are accountable to the IV&V Program Manager for programmatic success. The GSFC Program Management Council (PMC) is the governing PMC (GPMC) for the IV&V Program.

4.2 Responsibilities

For the IV&V Program, there are three principle levels of responsibility:

- IV&V functional management within Code Q, the IBD and GSFC Center Management;
- IV&V Program Management which resides at the IV&V Facility and is part of the GSFC organization and draws upon support from GSFC; and
- IV&V Project Management which is responsible for the implementation and conduct of IV&V Projects led by the IV&V Services group located at the IV&V Facility.

Each of the principle levels has a controlling document associated with it. These documents are the IV&V PCA, the IV&V Program Plan (this document), and a mission specific IV&V Project Plan (or equivalent) approved for each mission. Each mission will also have a software criticality and risk analysis performed that will be documented in a Software Assessment Report

(SAR). The organizational relationship of these entities is shown in Figure 1. The roles and responsibilities of these entities are described in the following sections.

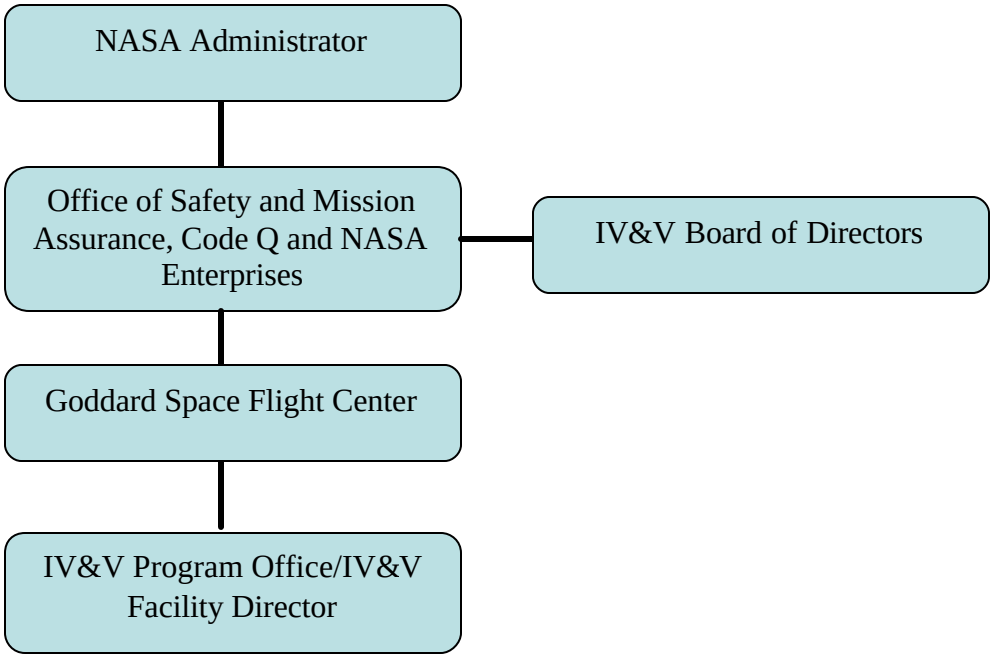

Figure 1 NASA Organization for the IV&V Program

4.2.1 NASA Headquarters

NASA Headquarters Code Q has the responsibility for the functional direction of the overall IV&V Program. In accordance with NPD 8730.4, the AA for Safety and Mission Assurance has the following responsibilities:

- Providing software IV&V executive leadership and policy direction for Enterprises, Projects, Programs, and managers throughout NASA, collaborating with the Enterprise AAs in developing policies for the conduct of software IV&V across NASA Enterprises, Programs and Projects;
- Ensuring Agency-wide implementation of strategies for the conduct of software IV&V commensurate with the Agency risk posture;
- Ensuring that the IV&V Program conducts its functions in an effective and efficient manner to facilitate application of software IV&V to NASA Programs, Projects, and operations;

- Supporting the research, development, and rapid transfer of new software IV&V technologies, tools, processes, and techniques consistent with laws, regulations, and NASA policy regarding technology transfer; and

- Establishing and chairing the IBD (comprised of Enterprise AAs, Chief Engineer, Chief Information Officer and the GSFC Center Director and Facility Director/IV&V Program Manager as IBD ex officio members).

The AAs for the NASA Enterprises have the following responsibilities:

- Collaborating with the AA for Safety and Mission Assurance in developing policies for the conduct of software IV&V across NASA Enterprises; and

- Participating as members of the IBD.

The IBD has the following responsibilities:

- Annually establishing the Agency level of funding for IV&V Projects based upon a proposed prioritized list of Projects provided by the NASA Chief Engineer's Office.

4.2.2 IV&V Program Office

The AA for Safety and Mission Assurance has delegated the management of the IV&V Program to the GSFC. The GSFC Director is responsible for overall Program success and is accountable to the AA for Safety and Mission Assurance. The IV&V Program Manager is accountable for directing a Program which meets NASA, Code Q and IV&V Program requirements within the established cost, schedule and performance boundaries. Specific responsibilities (under the role of the IV&V Facility Director) as defined in NPD 8730.4 include: (1) managing all software IV&V efforts, including the collection, analysis, and reporting of performance measures; (2) developing, acquiring, and maintaining state-of-the-art software IV&V tools and techniques; and (3) supporting the development of software IV&V training.

The IV&V Program Office has program management responsibility of IV&V project planning and scoping, implementation, closeout and archive. The IV&V Program Office is responsible for ensuring that each IV&V Project remains within its committed cost, schedule and performance requirements and meets its local community commitments for Education and Outreach, when appropriate. The IV&V Program Office is also responsible for meeting NASA requirements on Technology Transfer and Small Disadvantaged Business (SDB) and Minority Institutions. The IV&V Program Office promotes efficiencies through the application of innovative management practices, the identification and implementation of inter-project synergies, and the capture and application of lessons learned. The IV&V Program Office will perform the following specific responsibilities:

- Develop the IV&V Program Plan that documents the IV&V Program framework under which IV&V Projects can operate with developmental Projects;

- Approve IV&V Project plans and concur with the baselining of and changes to IV&V Project-specific cost and schedule updates;
- Formulate and manage the allocation of the IV&V Program budget; ensure appropriate distribution of funds to IV&V Projects based upon Agency decisions;
- Support Code Q with IV&V Program advocacy;
- Ensure open communication with IV&V Program customers;
- Conduct technical and resource management of all contracts and grants;
- Conduct continuing assessments of the programmatic progress of IV&V Projects including management and cost;
- Support appropriate reviews with the GSFC GPMC and Code Q and report overall IV&V Program status on a periodic basis;
- Make recommendations for continuation or termination of an IV&V Project to Code Q and the IBD;
- Develop, track and report measures of IV&V effectiveness;
- Identify and implement research needed to support and improve IV&V; and
- Provide IV&V Program budget requirements to Code Q in support of the annual POP calls.

4.3 Program Flexibility

It is recognized that the IV&V Program structure and processes will change over time in response to the needs of the Agency, feedback from developmental Projects and advancing technology. The IV&V Program Office will work with the OSMA, the IBD, and the GSFC to define and implement appropriate changes to the IV&V Program as applicable.

5 Program Requirements

The IV&V Program requirements are driven by the IV&V Program objectives and the NASA 2003 Strategic Plan, GSFC FY 2004 Implementation Plan and the IV&V Facility Implementation Plan.

5.1 IV&V Services

The primary role of the IV&V Program is to provide software IV&V services to the Agency's most mission/safety critical software development Programs and Projects. IV&V services focus on two goals when working with a developmental Project. The first goal is to provide assurance to the Agency that the mission/safety critical software being developed will be fit for operation and meet its requirements for safety, availability, quality, and function. The

second goal is to provide early lifecycle detection of errors, issues, and risks in the developmental Projects so that appropriate corrective actions can be taken to minimize system wide impacts to the development effort.

The IV&V services use a flexible, requirements-driven approach to software and system-level IV&V. The approach is requirements-driven in order to best achieve the second goal mentioned above. All of the tasks performed are based upon software verification and validation industry standards and applicable NASA standards. The tasking is documented in an IV&V services WBS. In order to account for the variability in software development approaches, the WBS is tailored at two levels. First, the WBS is tailored based on the type of Project being analyzed. Specifically, a human-rated Project, a robotic Project, an instrument only Project, or a data processing Project. Each of these types of Projects has a specific subset of tasks from the overall WBS associated with it.

The second level of tailoring is performed via an analysis process that identifies and categorizes the software components being developed by consequence and likelihood of failure. The output of this process is known as a Critical Functions List (CFL). The CFL is a ranked or prioritized characterization of the software components. This list is used to tailor the IV&V activities based on component risk. The final tailored approach to IV&V for each Project is documented in an IV&V Project Plan.

The IV&V Program strives to perform all of the tasks that are required to provide the appropriate level of IV&V on any given Project while keeping in sync with the development Project's schedule. However, the specific Projects to be supported are determined by the Project's priority in the Agency list and the approved budget.

5.2 Research

The IV&V Program is responsible for delivering high quality service to the Agency. No amount of IV&V can ensure that mission/safety critical software is completely error free or will perform correctly under all conditions throughout the life of the system. However, through careful study of the effectiveness of the IV&V techniques employed, the IV&V Program can certify that within technical, budget and schedule constraints, effort has been efficiently expended to assure that the product performs as expected and required. This level of confidence requires a robust research effort to determine the measures of IV&V effectiveness and baseline the effectiveness of the IV&V tasks employed. Additionally, the research effort must seek out and evaluate new and more effective approaches, methods, and tools to support IV&V. This search for optimal IV&V tools and techniques will entail the improvement of existing techniques as well as the development of new tools and techniques. Additionally, changes in technology such as the use of adaptive systems and the recent popularity of automatic code generators drive a need for new IV&V techniques.

The IV&V Program research effort is focused on addressing those research needs which are IV&V specific. Internal research activities are funded by a portion of the Agency's Software Assurance Research Program (SARP) budget and out of the Program's discretionary funds. The

SARP research addresses software assurance issues of general interest across NASA and is not directly targeted at IV&V methods, processes or activities; however, a portion of the Program is applicable to the IV&V Program.

The IV&V Facility has established a research management team to coordinate and manage the IV&V research effort. The team has established a research infrastructure to help manage and assess the research efforts. This infrastructure consists of:

- A data repository to store research results.
- A website for dissemination of research results.
- International Organization for Standardization (ISO) procedures to support public release of research results.
- ISO procedures and metrics for the evaluation of research progress.

5.3 Education and Outreach

A goal of the IV&V Program is to provide for a well-grounded and substantial education and outreach program. This is accomplished through three principle efforts at the IV&V Facility: the Educator Resource Center (ERC), Internships, and Cooperative Education.

5.3.1 Educator Resource Center

The NASA IV&V Facility, through a grant with West Virginia University (WVU), has established an on-site ERC, that provides resources and training opportunities which have significant educational impact in the classroom. The ERC provides in-service and pre-service educators with an accessible source of materials that reflect NASA's current research and technology. These materials relate to curriculum areas such as Human Exploration, Development of Space, Earth Science, Space Science, Aerospace Technology, and Biological and Physical Research.

The ERC staff provides free workshops for K-12 educators on a variety of topics to supplement the curriculum and help meet national and state standards. Since the establishment of the ERC in 1998, over 3,000 pre-service and in-service teachers have attended workshops sponsored by the IV&V Program.

5.3.2 Internships

The IV&V Facility strives to bring new talent to the Agency through internship and apprenticeship Programs. These Programs provide meaningful experience and exposure to the Agency for both high school and college (undergraduate) students. These Programs are described below:

Undergraduate College Internship Program – provides local undergraduates with the opportunity to apply academic skills to real-world problems. The interns work part-time

alongside engineers to provide added support to Projects and/or research within the IV&V Facility.

Science and Engineering Apprenticeship Program (SEAP) - provides local high school students experience and exposure to the world of scientific research. The Program offers apprenticeships for high school students who are U.S. citizens interested in science and engineering. The students are assigned to a scientist or engineer who serves as a mentor to the apprentice for eight continuous weeks during the summer.

Summer High School Apprenticeship Research Program (SHARP) - offers local high school students the opportunity to participate in an intensive science and engineering apprenticeship Program. High school students are selected on the basis of having shown aptitude for and interest in science and engineering careers. The Program operates during the summer months for a minimum of eight weeks. As apprentices, the students have the opportunity to learn and earn a salary.

5.3.3 Cooperative Education Program

The Cooperative Education Program is an important link in the educational process that integrates college level academic study with full-time meaningful work experience. This is achieved through a working agreement between GSFC and a number of educational institutions. This agreement allows the students, through study and work experience, to enhance their academic knowledge, personal development, and professional preparation. Additionally, Co-op employees earn income that is based on their level of education and work experience as well as receive civil servant benefits.

The NASA IV&V Facility benefits from the Co-op Program in many ways. The Program attracts students preparing for careers in a shortage category (engineering and science), permits selection for career jobs on the basis of proven performance, supports equal opportunity, and generally helps to more directly relate the efforts of educators to occupational needs of NASA and students. The IV&V Facility has an outstanding rate of conversion of Co-ops to permanent staff positions.

6 IV&V Program Support Planning

The IV&V Program will maintain a baseline of current IV&V requirements and commitments, and will work with the OSMA, Enterprises and Centers to periodically update a forecast of potential future missions and their software characteristics to support projections of IV&V workload, staffing, budgets and other resource requirements. This section describes the process used to develop this forecast.

6.1 Process for Developing Preliminary IV&V Mission Model

Forecasting support requirements for POP calls necessitate a method to estimate the level of IV&V support needed for missions very early in the mission planning or Formulation phase

when only limited information is available. Leveraging our lessons learned and historical knowledge of IV&V efforts, a mission model was developed to track missions that are candidates for software IV&V. Candidates are currently identified from multiple sources; NASA budget, Center and Program schedules, Center IV&V liaisons, etc.

6.2 Potential Mission List for IV&V

The preliminary IV&V mission model resulting from the process described in Section 6.1 comprises the initial estimate of those Projects that, due to apparent software criticality and risk, may benefit from the application of software IV&V. The determination of whether IV&V is actually performed on a Project, the software elements to focus on, and the size of the effort required, will be based on a more detailed analysis of the probability of software failure and of the impact of software failure on the mission. This determination is then subject to review by the Enterprises and the IBD. The final decision regarding which Projects will receive IV&V is made by the OSMA.

Initial IV&V estimates are updated by working directly with NASA Projects. The results of working with those Projects nearing their launch dates were incorporated to produce an updated IV&V mission model in March 2001; the Mission Model has been continually updated since. This model documents the potential future work for the IV&V Program and provides the basis for the resource planning process described in Section 7.

In order to maximize the benefits of IV&V to Projects under development, the Facility will work with management at NASA Centers to assist the OSMA, IBD and Chief Engineer in establishing priorities.

6.3 Process for Updating IV&V Mission Model

The Facility will work with Code Q to regularly update the IV&V mission model to ensure a commonly understood basis for planning future IV&V efforts and budgets. Information on potential future missions will be drawn from Enterprise plans, Center Programs, Announcements of Opportunity (AO), Office of the Chief Engineer, the IBD and other sources. Mission characteristics and expected IV&V requirements will be identified by applying the IV&V criteria, which are contained in a self assessment survey that is completed by each Project (this survey is maintained at http://criteria.ivv.nasa.gov/). Estimated budgets and staffing requirements will be developed as described in Section 7. The overall update process for IV&V planning is described in the last few paragraphs of Section 7.1.

7 Program Resources

Using the IV&V mission model developed as described in Section 6, Program personnel utilize historical knowledge of past IV&V efforts to estimate the resources necessary to support the Projects identified as potentially needing IV&V. These resources include estimated cost by Project, projected contractor staffing at the Facility and at development sites, civil service staffing required for the management of IV&V application and technology Programs, and

Facility space, computing, networks and other resources. Resource estimates reflect an IV&V approach for complete lifecycle activities; however adjustments to this approach may be initiated based upon determination of funding levels and priority.

7.1 Process for Developing IV&V Resource Estimates

The Facility has been performing IV&V on selected NASA Projects since 1994. This experience base is used to apply historical knowledge to the IV&V mission model described in Section 6 to determine an initial staffing estimate and cost profile for each Project in the mission model. The IV&V Facility utilizes three different estimation processes, depending where the mission is in its lifecycle, to develop and refine our resource estimates as described in the subsections below.

7.1.1 Initial (prior to available software estimates)

- For those Projects where agreements already exist for the performance of work by the Program, cost and personnel requirements are taken from those agreements and where appropriate, out-year projections are made.
- For Projects having no current Program involvement, an estimate is made of the level of personnel support required based on Project attributes and schedule, as well as on the IV&V Program's past experience with similar Projects. The following general approach is used:
  - Projects are classified by Program (e.g. Discovery, Small Explorers (SMEX), Earth System Science Pathfinder (ESSP)) which is an indicator of Project type (e.g. *Space Vehicle (not human-rated), Planetary/Deep Space Vehicle, Planetary Lander or Atmospheric Vehicle (not human-rated)*). Resources are estimated based upon Program models that are contained within the mission model (which is refined as needed). In general, IV&V personnel perform IV&V at full staff loading from three months before the start of the Implementation phase to six months after delivery. Fifty percent of the full staff loading was assumed to be required from the projected start date until three months before Implementation. Fifty percent of the full staff loading was assumed from six months after delivery until six months after the mission is operational.
  - Where additional information is known, and it is clear that the programmatic model is not sufficient, a Project specific model is developed and captured in the mission model.
  - Large Projects and human-rated flight missions require larger IV&V teams. Staffing for these Projects is determined on a case-by-case basis.
  - Knowledge of any mission-unique characteristics is applied to these estimates (e.g., the Mars 2003 mission has two landers, so the estimate for that mission was increased).

- Estimates for future NASA Projects (e.g., Discovery missions 09 through 12) are made based upon Project type and schedule.
- Civil servants are assigned responsibility as IV&V Project Managers for each of the customer Project IV&V efforts.
- Contractor and civil service staffing profiles are then appropriated based upon the phasing of each Project during each FY.

- Finally, costs are assigned based upon the number of contractor full-time equivalents (FTEs) indicated per FY. Recognition was given in these computations that personnel costs are necessarily higher per person on smaller Projects due to a greater percentage of work involving analysis versus performing routine procedures.

Once the above resource estimation is performed, the results are provided to Code Q and then ultimately to the IBD.

7.1.2 Software Characteristics Available

The second method for generating resource estimates uses Project-specific information (software size or function points, percent reuse, coding language, etc.) to refine the initial estimates generated based upon generic mission characteristics.

There are significant uncertainty factors in the above estimates. Actual Project costs may vary from these estimates after software risk analyses are performed. However, for the purpose of estimating total IV&V Program resources, individual Project variances should tend to offset in the summation process. The resulting budget estimate provides a basis for the IV&V Program to plan civil service staffing requirements, contracts, and other resources needed to support the NASA mission model.

7.1.3 Startup

Subsequent to the development of IV&V Program resources plans, the staff of the Facility will work with IV&V Project Managers to refine IV&V plans and cost estimates based on a risk analyses, and will adjust the IV&V Program plans accordingly. This method for generating resource estimates is generated after a criticality and risk assessment is performed by IV&V for the Project. This assessment uses detailed Project information to assess the risk and criticality of individual software functions. This process provides the basis for the final refinement of the IV&V resource estimates.

7.2 IV&V Workforce

The IV&V civil servant workforce represents a critical component for the successful implementation of the IV&V Program. The majority of this workforce is comprised of Project Managers and Project Engineers providing “hands-on” support to the IV&V services being conducted. Workforce resources in IV&V Services, Research, and Education and Outreach will be required to support the IV&V Program work forecast. Under full-cost accounting, civil

service salaries, travel, and training are included. Current as well as projected workforce levels will be documented annually in a separate operating plan.

7.3 Facilities

The NASA IV&V Program is managed out of a facility located in North Central West Virginia. The NASA IV&V Facility was constructed in 1993 via a NASA grant to the WVU as part of an Agency-wide strategy to provide the highest achievable levels of safety and cost-effectiveness for mission/safety critical software. WVU owns the building and is under contract to provide the building for NASA exclusive use as well as operations and maintenance services. In an agreement between NASA and WVU, NASA leases excess raised floor computer space to other government agencies in order to offset NASA's operations and maintenance costs associated with the Facility.

The NASA IV&V Facility is a high quality 55,000 square foot, two story building located in a Technology Park in Fairmont, West Virginia. The first floor consists of a 15,800 square foot mechanical area and approximately 19,600 square feet of high quality raised floor computer space. The 19,600 square feet on the second floor is primarily configured for offices, open cubicle space, and conference rooms. The Facility's infrastructure is backed up by redundant Uninterruptible Power Supply (UPS) systems supported by batteries and diesel generators. Communication to and from the Facility is provided by numerous vendors for multiple purposes. The NASA Integrated Services Network (NISN) provides NASA connectivity to the rest of the Agency. The National Weather Service (NWS), who is a tenant of the building, employs T-1 communication lines through a local carrier. The Facility also provides connectivity to a broadband fiber optic circuit for research entities located within the building as well as others within the North Central West Virginia area.

The IV&V Facility houses both NASA civil servants as well as NASA contractors. Because the Facility is fully occupied, IV&V contractors have also secured additional local office space outside of the IV&V Facility building. IV&V contractors are also located across the country relative to where IV&V is being performed for NASA Projects. The NASA IV&V Facility is a high quality facility that provides NASA with a centralized capability to facilitate IV&V and IV&V related research activities.

8 Controls

The IV&V Program has both programmatic level controls and project level controls. The goal of each of these is to ensure that the Program and the Projects are meeting the requirements set forth by the Agency. These controls are an integral part of the IV&V Management System (IMS), which is an ISO 9001 registered system, and are described further below.

8.1 Technical Performance

Each IV&V Project Manager will perform a criticality and risk assessment of the mission software elements and development approach. A software critical functions list and IV&V

Planning and Scoping Report (PSR) will be prepared and reviewed with mission Project Managers and software leads. These products will serve as the initial IV&V technical approach baseline included in the mission IV&V Project Plan. An abbreviated version of this process will be repeated on a periodic basis throughout the life of the mission development lifecycle to ensure that the highest criticality and risk areas receive appropriate IV&V.

Mission IV&V status will be presented regularly at monthly and quarterly mission status review meetings, mission software reviews, etc. IV&V will participate in regularly scheduled mission status meetings. Formal and informal IV&V assessment reports will be provided to mission Project Management at the completion of each major IV&V task. IV&V Project Managers will present an overview of the IV&V activities and finding at each major milestone review and the launch readiness reviews. IV&V will be prepared to make a recommendation regarding software readiness at the end of the development lifecycle prior to the launch and operation phase. Associated metrics will be collected and reported via the IMS and periodic reports. Other IV&V initiatives will be included in the Annual Operating Agreement (AOA) and reviewed periodically by the IV&V Program Manager, GSFC, Code Q and the IBD.

8.2 Cost

The IV&V Program will prepare an itemized budget each year for the Agency's annual POP call. This submission will contain a list of missions and Projects scheduled for IV&V services in the POP year along with research initiatives, operations and maintenance costs and other anticipated direct and indirect costs. This submission will be reviewed by the IV&V Program Manager, GSFC and Code Q. Code Q approves and advocates the budget. The list of Projects selected for IV&V by the IBD will then used as the baseline for IV&V execution. This budget plan will continue to be refined until the beginning of the execution POP year.

During the year of budget execution, the approved budget will be actively managed. Funding may be reallocated amongst individual IV&V Projects based on Agency and/or programmatic dynamics.

At the Project level, costs are controlled via various means including conducting monthly budget reviews, analysis and tracking of contractor's 533 reports (on both a monthly and quarterly basis) and collection of and reporting of earned value management data at Facility Project Management Reviews (PMRs).

8.3 Schedule

The IV&V Program will maintain a high level schedule consistent with the mission development lifecycles and the Agency funding profile. This schedule will be reviewed and approved by the IV&V Program Manager, GSFC and Code Q.

Each IV&V Project will have a detailed IV&V schedule consistent with the mission development lifecycle and annual Agency funding for that mission's IV&V. These schedules will be included in PSRs and Project Plans and will serve as the mission IV&V schedule

baseline. Associated schedule metrics will be maintained and reported to the IV&V Program Manager, GSFC and Code Q.

9 Relationships to Other Programs and Agreements

The IV&V Facility works directly with developmental Projects to reach concurrence on tasks to be performed and their associated timelines. This concurrence is generally documented in formal agreement which is signed by both the Project and the Facility. This agreement also provides points of contact, methods of communication, deliverables, and artifacts required.

The IV&V Program identifies software assurance research needs to the Code Q SARP. These needs may cover tools and processes to address new software development technologies and/or to improve the efficiency or effectiveness of IV&V. The IV&V Program then transitions the SARP developed tools or processes into IV&V practice.

The IV&V Program participates in all NASA Engineering and Safety Center (NESC) software discipline assessments conducted by the software Super Problem Resolution Team.

10 Acquisition Strategy

IV&V services are currently contracted via multiple vehicles, a cost plus fixed fee/incentive fee omnibus contract and three General Services Administration (GSA) blanket purchase agreements. In 2005, it is anticipated that a single IV&V services contract vehicle with multiple awards will be established.

The operations and maintenance of the IV&V Facility is contracted to WVU. This service provides support for Facility infrastructure and operations, information technology infrastructure and operations, and a technical library. Educational outreach activities and services are secured under separate grants with the applicable institution.

The IV&V Program will assist NASA in achieving its goal for the participation of SDBs, Women-Owned Small Businesses (WOSBs), Historically Black Colleges and Universities (HBCUs), and Other Minority Educational Institutions (OMEIs) in NASA activities. Contracts resulting from IV&V Program procurements will be required to contain a subcontracting plan that includes goals for subcontracting with these entities.

11 Data Management

Various data items, artifacts and records will be generated at both the Program and Project levels. These items will be managed in accordance with NASA Policy (including but not limited to NPD 1440.6 Records Management, NPD 2190.1 Export Control Program, NPD 2800.1 Managing Information Technology, and NPD 2810.1 Security of Information Technology), NASA Procedural Requirements (NPRs) and the procedures contained in the IMS.

At the Program level, items that are expected to be subjected to these policies, requirements and procedures include but are not limited to controlling documents such as the IV&V PCA, this

Program Plan, Operating Plans, IV&V mission model, etc. At the Project level, items that are expected to be subjected to these policies, requirements and procedures include process and product related artifacts as identified in the IMS.

12 Risk Management

The IV&V Program maintains a continuous risk management process that is utilized as a decision-making tool at both the Program and Project levels. This continuous risk management process has been established in accordance with NPR 8000.4 Risk Management Procedures and Guidelines.

At the Program level, risks are identified as part of our strategic planning, program management and resource planning activities, as well as our quarterly management reviews conducted as part of our IMS efforts. Risks are analyzed, tracked, controlled and communicated as appropriate.

At the Project level, risk identification is initiated prior to the start of the actual IV&V Project and continues throughout the Project lifecycle. Risks are documented, analyzed and an approach to address the risk is developed. The IV&V Project Manager tracks, controls and manages these risks throughout the Project lifecycle. Risks are routinely reviewed and reported at various forums including the IV&V Facility PMRs, GSFC GPMC and Code Q as appropriate.

At the Project level, risks associated with schedule and finances are typically encountered. These risks are managed through financial and schedule reserves, when available, and descoping of IV&V analysis tasks when appropriate.

13 Reviews

The IV&V Program includes and actively supports various reviews at both the Program and Project levels. At the Program level, bi-monthly progress summaries for each of the Projects receiving IV&V are presented at the Code Q General Management Reviews (GMRs). Monthly IV&V progress summaries for developmental Projects are also presented at the Goddard PMC. As part of our IMS, quarterly management reviews are conducted to review the state of the IV&V Program and financial/budget reviews are conducted monthly to assess the cost of the IV&V Program. In addition, per the PCA, OSMA will perform an annual independent review/evaluation of the effectiveness and efficiency of the IV&V Program.

At the Project level, reviews are supported from both an internal and external perspective. Internally, PMRs are conducted on a regular basis to provide status of the IV&V activities on a certain Project. Externally, IV&V supports all Project lifecycle reviews (System Requirement Review (SRR), Preliminary Design Review (PDR), Mission Readiness Review (MRR), etc), as well as other Project related reviews including but not limited to management reviews.

14 Change Log

Any changes to this Plan must be approved by the signatories on this document. The IV&V Program Office will maintain configuration management of this document.

Rev No	Description of Change(s)	Effective Date
N/A	Original	June 2001
1	Update of original IV&V Program Plan, dated 06/2001.	May 2004

Acronyms

AA	Associate Administrator
AO	Announcements of Opportunity
AOA	Annual Operating Agreement
ARC	Ames Research Center
CFL	Critical Functions List
DoD	Department of Defense
ERC	Educator Resource Center
ESSP	Earth System Science Pathfinder
FTE	Full-time Equivalent
FY	Fiscal Year
GMR	General Management Review
GPMC	GSFC Program Management Council
GSA	General Services Administration
GSFC	Goddard Space Flight Center
HBCU	Historically Black College and University
IBD	IV&V Board of Directors
IFMP	Integrated Financial Management Program
IMS	IV&V Management System
ISO	International Organization for Standardization
IV&V	Independent Verification and Validation
JPL	Jet Propulsion Laboratory
MRR	Mission Readiness Review
NESC	NASA Engineering and Safety Center
NISN	NASA Integrated Services Network
NPD	NASA Policy Directive
NPR	NASA Procedural Requirements
NRC	National Research Council
NWS	National Weather Service
OMEI	Other Minority Educational Institution
OSMA	Office of Safety and Mission Assurance
OSSMA	Office of Systems Safety and Mission Assurance
PCA	Program Commitment Agreement
PDR	Preliminary Design Review
PMC	Program Management Council
PMR	Project Management Review
POP	Program Operating Plan
PSR	Planning and Scoping Report
SAR	Software Assessment Report
SARP	Software Assurance Research Program
SDB	Small Disadvantaged Business

SEAP	Summer Engineering Apprenticeship Program
SHARP	Summer High School Apprenticeship Research Program
SMEX	Small Explorers
SRR	System Requirements Review
UPS	Uninterruptible Power Supply
WBS	Work Breakdown Structure
WOSB	Women-Owned Small Business
WVU	West Virginia University

Traceability of Performance Goals

The table below provides traceability between the IV&V Program objectives, performance goals and subgoals.

Program Objective	Performance Goal	Subgoal
IV&V Services	Institutionalize IV&V services throughout NASA as a natural 'best practice' and as a wise investment of time and resources.	a. Ensure IV&V is applied appropriately throughout the Agency. b. Become recognized as valuable throughout the ranks of NASA Projects and software managers. c. Gain NASA-wide recognition of IV&V being instrumental to mission success. d. Become more involved in NASA non-mission-specific Projects (i.e., all software critical to NASA functioning). e. Establish a NASA-wide environment in which Project Managers seek out and welcome IV&V Facility participation.

Program Objective	Performance Goal	Subgoal
IV&V Services, IV&V Research	Become nationally recognized as a preeminent leader in IV&V expertise, tools, and processes.	a. Create a culture of continuously improving the discipline of IV&V. b. Have IV&V tools, processes, and methods that address the changing technology of software development. c. Routinely transfer IV&V technology both internally and to others outside the NASA IV&V organization. d. Be a respected and valued resource for software and systems conferences, publications, and standards committees.
IV&V Research	Develop fully a recognized and valued IV&V research presence.	a. Do precedent-setting research and publish results. b. Objectively show value for IV&V. c. Enhance IV&V practitioners and researchers collaborative work.

Program Objective	Performance Goal	Subgoal
IV&V Services, IV&V Research, Outreach	Establish a desired organizational culture that engages and rewards employees and cultivates their long-term commitment to the NASA IV&V organization's workforce.	a. Cultivate a flexible and efficient workforce to support mission objectives b. Acquire and sustain a vital workforce (e.g., hiring, recruiting, retention). c. Provide appropriate training and personal growth opportunities for NASA IV&V employees. d. Establish the NASA IV&V organization as a diverse, unified team. e. Foster on-going recognition of employees based on performance and contribution to the Facility.
IV&V Services, IV&V Research, Outreach	Ensure a focus on customers that is second to none.	a. Refine our institutional and administrative functions to enable efficient, effective, and accurate support to our customers. b. Maintain an active and fully compliant ISO process as it relates to customer satisfaction. c. Develop a customer 'first and foremost' way within the IV&V culture. d. Ensure open lines of communication with all customers.

Program Objective	Performance Goal	Subgoal
IV&V Services, IV&V Research, Outreach	Achieve continued quality improvement, compliance, and innovation throughout the NASA IV&V organization that advance effective and efficient operations.	a. Create administration business processes that reduce workload on project managers and other staff. b. Instill practices and rewards that foster innovation and creativity in all areas of the NASA IV&V organization. c. Improve the quality and explicitness of our processes to maintain a standard at or above the ISO requirements.
IV&V Services, IV&V Research, Outreach	Capitalize on appropriate direct and collaborative opportunities to ensure maximization of existing resources and advance planned future growth.	a. Pursue other activities to enhance long-term growth of the NASA IV&V organization. b. Seek effective collaborative opportunities that will advance the NASA IV&V organization's vision and mission. c. Expand customer base (within NASA and other government agencies).

Program Objective	Performance Goal	Subgoal
Outreach	Be an active partner in our communities' future through educational and community outreach activities, and proactive service.	a. Encourage and enable employees to participate in community activities. b. Increase the awareness of the NASA IV&V organization within the community it serves. c. Provide resources and training opportunities related to science, math, and technology for pre-service and in-service teachers which will have a significant educational impact in the classroom.
IV&V Services, IV&V Research, Outreach	Ensure a safe, comfortable, and well-equipped workplace that is conducive to high performance and supports individual and team productivity.	a. Enhance the Facility's infrastructure to support all other goals and objectives. b. Ensure all aspects related to safety and security are monitored and addressed when improvement or compliance is needed. c. Provide for co-location of NASA IV&V staff and contractors within the same locality.